10/511392
DT05 Rec'd PCT/PTO 15 OCT 2004
ENGLISH TRANSLATION

WO 03/086809 PCT/DE03/01139

Description

Method for electrodynamically braking a rail vehicle

The invention relates to a method for electrodynamically braking a rail vehicle which is equipped with a drive and is in particular a tram.

Until now, electrodynamic brakes have not been used up to the point where the rail vehicle comes to a standstill. An existing mechanical brake has always been used below a velocity of 2 km/h to 7 km/h. In this context there is the disadvantage that when the rail vehicle comes to a standstill there is a jolt which is uncomfortable for the passengers.

Braking as far as the point where a vehicle comes to a standstill was hitherto not carried out with electrodynamic brakes because at low velocities the braking force was subject to large fluctuations which are due in particular to the route (positive or negative gradient).

The invention is based on the object of specifying a method for electrodynamically braking a rail vehicle which permits safe braking to the point where the vehicles comes to a standstill so that the mechanical brake which causes an undesired jolt is normally not used and as a result is also subject to less wear.

The object is achieved according to the invention in that the acceleration of the rail vehicle is controlled as a function of its velocity.

This provides the advantage that optimum deceleration (negative acceleration) is possible at any velocity of the rail vehicle, even at a very low velocity. It is therefore possible to bring the rail vehicle to a

standstill solely using the electrodynamic brakes. The electrodynamic brakes operate advantageously without a jolt.

The acceleration of the rail vehicle is, for example, controlled to a set point acceleration which is proportional to the negative root of the velocity. For this purpose, this relationship can be stored as a characteristic curve $a_{step} = - k \cdot \sqrt{v}$.

According to another example, the acceleration of the rail vehicle is regulated to a set point acceleration which is proportional to the velocity. This relationship can also be stored as a characteristic curve.

The set point acceleration can also for individual sections (route sections or travel time periods) which follow one another be either in proportion to the velocity or to the negative root of the velocity. There results a characteristic curve composed of linear and root-type sections.

During the braking process, the respective current set point acceleration is determined with the characteristic curve from the velocity of the rail vehicle and the current acceleration is controlled in such a way that it corresponds as far as possible to the set point acceleration.

Influences of the route being traveled on (positive or negative gradient) are compensated by the control of the acceleration.

For example, the acceleration can be controlled indirectly by controlling the torque of the drive of the rail vehicle. The torque can be controlled comparatively more easily than with direct control of the acceleration.

In order to control the torque it is possible to use, for example, a PI controller.

For example, during the control process it is possible to provide for the torque always to be kept within predefined limits. These limits are predefined, for example, by the driver.

For example, an additional torque, which is proportional to the set point acceleration, is added to the torque for the sake of pilot control. Here, the proportionality constant is dependent on vehicle values.

This provides the advantage that influences which are due to the design of the vehicle itself are ruled out entirely or largely.

The vehicle values are, for example, in particular the vehicle mass, but also the transmission ratio and/or the diameter of the wheels.

The instantaneous velocity of the rail vehicle is determined, for example, from the rotational speeds of the drive and/or of an axle.

The set point acceleration is then determined, for example, using the characteristic curve which represents the set point acceleration as a function of the velocity. The set point acceleration is, for example, proportional to the negative root of the velocity.

The instantaneous acceleration is determined, for example, as a first derivative of the velocity which is determined. A direct comparison between the instantaneous acceleration and the set point

acceleration is then possible, and the acceleration can be controlled.

The drive of the rail vehicle is generally an asynchronous machine with a pulse-controlled inverter. If the drive has a coupling of an I-n model to a U model of an engine, the acceleration can be controlled particularly satisfactorily to a point where the rail vehicle comes to a standstill.

The method according to the invention can be used for a general control of the travel of the rail vehicle. In particular, the method is well suited to braking a rail vehicle to the point where it comes to a standstill without a mechanical brake having to be applied. It is therefore advantageously ensured that the vehicle will stop without a jolt.

The method according to the invention for electrodynamically braking a rail vehicle will be explained in more detail with reference to the drawing:

At first the velocity v of the rail vehicle is determined 1. The instantaneous acceleration a_{act} is determined 2 from the velocity value after the first derivative of the velocity profile has been formed.

In parallel with this, the set point acceleration a_{step} is determined 3 from the velocity v using a predefined characteristic curve. According to the characteristic curve, the set point acceleration a_{step} is proportional to the negative root of the velocity v with the proportionality constant k.

Both the instantaneous acceleration a_{act} and the set point acceleration a_{step} are fed to the controller 4 which may be a PI controller. The torque M_R which is necessary for the desired control of the instantaneous

acceleration a_{act} to the set point acceleration a_{step}, for the drive 6, is output at the output of the controller 4.

In order to compensate influences due to the rail vehicle itself, an additional torque M_v in addition to the already calculated torque M_R is added before the drive 6 is actuated. This additional torque M_v is determined 5 by the product of the set point acceleration a_{step} and a proportionality constant m, which may be dependent on the vehicle mass, the transmission ratio and/or the diameter of the wheels.

The sum of the torques $M_R + M_V$ is fed to the drive 6 where the acceleration a_{act} of the rail vehicle is controlled by means of the torque $M_R + M_V$.

The rotational speed n of the drive 6 is used to determine the velocity v of the rail vehicle and is made available by the drive 6 in order to determine the velocity 1.

The method described makes it possible to control the acceleration (deceleration) of the rail vehicle in a uniform fashion, in particular to the point where the vehicle comes to a standstill.

Patent claims

1. A method for electrodynamically braking a rail vehicle which is equipped with a drive (6), characterized in that the acceleration (a_{act}) of the rail vehicle is regulated as a function of its velocity (v).

2. The method as claimed in claim 1, characterized in that the acceleration (a_{act}) is regulated to a set point acceleration (a_{step}) which is proportional to the negative root of the velocity (v).

3. The method as claimed in claim 1, characterized in that the acceleration (a_{act}) is regulated to a set point acceleration (a_{step}) which is proportional to the velocity (v).

4. The method as claimed in claims 2 and 3, characterized in that the set point acceleration (a_{step}) for individual sections is either proportional to the negative root of the velocity (v) or proportional to the velocity (v).

5. The method as claimed in one of claims 1 to 4, characterized in that in order to control the acceleration (a_{act}) indirectly, the torque (M_R) of the drive (6) is regulated.

6. The method as claimed in claim 5, characterized in that a PI controller is used to control the torque (M_R).

7. The method as claimed in one of claims 5 or 6,

characterized in that when the torque (M_R) is controlled it is kept within predefined limits.

8. The method as claimed in one of claims 5 to 7, characterized in that an additional torque (M_V) which is proportional to the set point acceleration (a_{step}) is added to the torque (M_R), and in that the proportionality constant is dependent on vehicle values.

9. The method as claimed in claim 8, characterized in that the vehicle values are the vehicle mass, the transmission ratio and/or the diameter of the wheels.

10. The method as claimed in one of claims 1 to 9, characterized in that the velocity (v) of the rail vehicle is determined from rotational speeds (n) of the drive (6) and/or of an axle.

11. The method as claimed in one of claims 1 to 10, characterized in that the acceleration (a_{act}) is determined as a first derivative of the velocity (v).